Using ^{18}O to Partition Ecosystem Carbon Exchanges: Impact of the Near-Surface $\delta^{18}O$ Value of Soil Water on the $\delta^{18}O$ Value of the Soil-Surface CO_2 Flux

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RESEARCH OBJECTIVES

The ^{18}O content of atmospheric CO_2 has been proposed as a means to partition site-level measured net ecosystem carbon fluxes into component gross fluxes and, at the global scale, to estimate the regional distribution of CO_2 fluxes. However, these approaches require accurate prediction of the $\delta^{18}O$ value of the soil-surface CO_2 flux (δF_s). This work aims to better characterize and to improve the computational efficiency of models used in global and regional simulations.

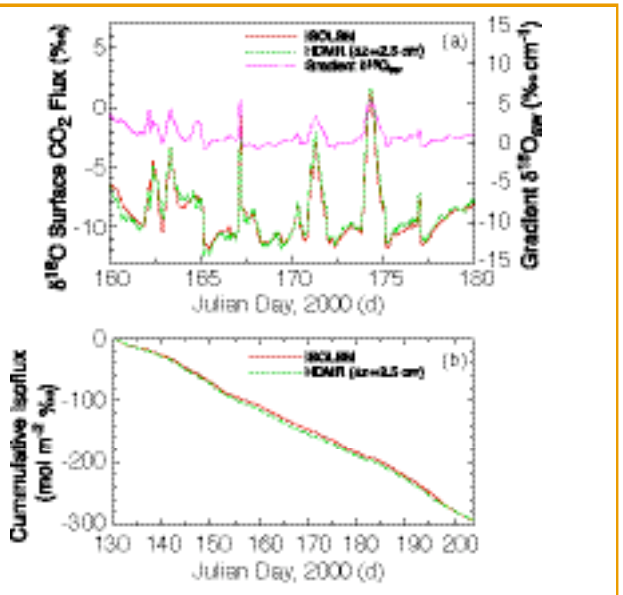

Figure 1 (a) δF_s as predicted by ISOLM and the HDMR approach. Also shown is the gradient in δ_{sw} over the top 15 cm. (b) Cumulative isoflux from the soil to the atmosphere for the two approaches. The error the three-month growing season was 0.2%.

APPROACH

The net $C^{18}OO$ surface flux depends, nonlinearly, on the depth-dependent $\delta^{18}O$ value of soil water (δ_{sw}), soil moisture and temperature, soil CO_2 production, and the $\delta^{18}O$ value of above-surface CO_2 (Riley, 2003a). We developed ISOLSM (Riley et al., 2002; Riley et al., 2003b) to simulate these processes within an established land surface model (LSM1). ISOLSM simulates the ^{18}O content of canopy water vapor, leaf water, and vertically resolved soil water; leaf photosynthetic $C^{18}OO$ fluxes; CO_2 oxygen isotope exchanges with soil and leaf water; soil CO_2 and $C^{18}OO$ diffusive fluxes (including abiotic soil exchange); and ecosystem exchange of $H_2{}^{18}O$ and $C^{18}OO$ with the atmosphere. Since ISOLSM is a computationally expensive model, we applied a high-dimension model representation (HDMR) technique to efficiently predict δF_s.

ACCOMPLISHMENTS

Our results indicate that the HDMR approach is very accurate and about 100 times faster than the full numerical solution of the $C^{18}OO$ surface flux, making it appropriate for regional and global simulations. We successfully tested the HDMR approach over a growing season at a C_4-dominated tallgrass prairie site, and then used the model to investigate the factors important in determining δF_s. The top panel of the figure shows comparisons between the full numerical model and the HDMR approach for a 20-day period. The bottom panel shows comparisons of the cumulative isoflux from the soil surface over the full season; the error over the growing season was less than 0.2%. The largest changes in δF_s occur when gradients in the top 5 cm are large. These conditions typically occur when soil evaporation is large, i.e., following precipitation.

SIGNIFICANCE OF FINDINGS

Simulation results indicate that δF_s is dependent on the $\delta^{18}O$ value of soil water in the top few centimeters of soil. These results indicate that recent approaches to estimating global distributions of the surface $C^{18}OO$ flux are problematic and demonstrate the importance of accurately resolving near-surface δ_{sw}. Also, the development of the HDMR approach allows for accurate and computationally affordable simulations of regional and global distributions.

RELATED PUBLICATIONS

Riley, W.J., Impact of the near-surface $\delta^{18}O$ value of soil water on the $\delta^{18}O$ value of the soil-suface CO_2 flux: Application of a high-dimension model representation technique. GRL, 2003a (submitted).

Riley, W.J., C.J. Still, M.S. Torn, and J.A. Berry, A mechanistic model of $H_2{}^{18}O$ and $C^{18}OO$ fluxes between ecosystems and the atmosphere: Model description and sensitivity analyses. Global Biogeochemical Cycles, 16, 1095–1109, 2002.

Riley, W.J., C.S. Still, B.R. Helliker, M. Ribas-Carbo, S. Verma, and J.A. Berry, Measured and modeled $\delta^{18}O$ in CO_2 and H_2O above a tallgrass prairie. Global Change Biology, 2003b (in press).

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